## Construction and efficiency of crystal receiving sets in wireless telephony by D. W. Everson.

*Communicated by* R. D. Thompson.

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For headphone reception within twenty miles of a broadcasting station the crystal detector has many advantages, being easy to operate, pure in tone, and cheap to instal and maintain. During the past ten years very little scientific work has been done with crystals, as valves received most of the attention, but there are now signs of renewed interest in crystal-reception. Wonderful improvements are being made in the production of synthetic crystals of great sensitivity, and there is no doubt that when we understand the principle of contact rectification better, crystal sets will afford a very convenient means for the reception of broadcast telephony.

A complete receiving set comprises aerial, earth connection, detector, and some means of tuning the aerial and telephone receivers.

*Aerial.*—Since the whole of the energy available for conversion into sound has to be drawn from the ether by means of the aerial, and there is no means of adding to this energy by any local source, it is essential that the aerial should be as high as possible and well insulated. In a series of experiments carried out on crystal receivers, 100ft. of 16G. wire, 20ft. high, were used as an aerial, it being considered that these dimensions were the most suitable for suburban residents, although an increase in height, length and area of cross-section of wire would be an improvement. The lead-in wire should preferably be insulated, and should enter the building through a tube insulator, thus reducing the losses to a minimum.

*Earth Connection.*—A good contact to earth is necessary and can usually be obtained by soldering an insulated wire to a water pipe, or in the absence of a water supply, by burying a metal plate edgewise in the ground. Best results are obtained when the ground is damp.

*Detectors.*—These are procurable in a variety of makes, and the only requirement is that the contact at the ''ball fitting'' should be sound and lend itself to easy adjustment.

*Aerial Tuning.*—Every aerial has its own or fundamental wavelength, which varies in different aerials according to size and local conditions. When it is desired to receive signals or music from a given station, it is necessary to reduce or increase the natural wave-length of the aerial to that of the station. This can be accomplished in a number of ways, but as we are considering sets suitable for our local station, 6 W.F., we shall confine ourselves to methods of increasing the natural wave-length to 1250 metres. Taking 200 metres as a fair average for the natural wave-length of an aerial, we see that it will be necessary to load up to the extent of about 1050 metres. The question at once arises as to the best way of doing this. There are at least five possible ways, viz.—by adding inductance (i) tuned by a series condenser, (ii.) tuned by a parallel condenser, (iii) variometer tuned, (iv.), tuned by sliding contact, (v.) tuned by tapping. From a number of experiments carried out in which headphones were used for detecting the variations of intensity, no decided difference could be found in the efficiency of any particular set. It is, however, well known that as a gauge of comparatively small differences of intensity the ear is very defective. With sounds of moderate intensity 5 per cent. is probably the best accuracy of comparison that can be obtained. If the time interval between the sounds is ten or fifteen seconds, or even more, it is doubtful whether a 50 per cent. change can be detected with any certainty. There is thus very little to be gained by unnecessarily striving after the utmost efficiency, although of course a reasonable efficiency is essential. We may summarise the results obtained by the use of the different circuits as follows:—

*Series Condenser Tuning.*—While this arrangement of condenser tuning is very popular, it is not found satisfactory for crystal reception. The condenser losses are high, and gradually increase as the scale readings decrease. This is to be expected, as there is almost a break in the aerial lead when the condenser is at zero.

*Parallel Condenser.*—This is an improvement on the previous method, as the condenser losses are more nearly constant.

*Inductance Tuning.*—By far the best results are obtained when inductance only is used for loading. This may be accomplished by three different methods, but there is so little difference between the results obtained that mechanical construction, compactness, and general lay out decide which is the best method to adopt. The sliding contact system is not considered mechanically sound, there being a tendency to displace the end turns, a defect which will become more pronounced during the summer months. The tapped coil system is very good and easy to construct, but the method of variometer tuning is undoubtedly the best. Variometers are capable of a high degree of efficiency, and reduce the dead-end effect to a minimum. They are mechanically strong, and if constructed to the details given below, they will be found to give every satisfaction.

It is found that in every instance single layer coils are superior to the "plug in" type. As to the relative merits of coupled and single circuits, I am in favour of the single circuit for local broadcasting. It is much simpler to operate, costs 50 per cent. less, and is more efficient on a wave-length of 1250 metres, since in a coupled circuit the coupling, to be of any use, must be loose. The chief advantage of the coupled circuit lies in its remarkable selectivity. This, however, will be of little value in the reception of 6 W.F., as the only interference comes from the Applecross Station, which is at present undergoing alterations, and will eventually use continuous wave signals of a wave length much shorter than that of the broadcasting station. Even these signals will be curtailed to an absolute minimum during concert hours. As an example of the relative efficiency of a single circuit on two different wave lengths, we may take the case of 350 metre transmissions. If the wave-length of the aerial is equal to 150 metres, it will be necessary to add loading equal to 200 metres. Now the crystal is placed across the loading coil and therefore is across 200/350 × 100 = 57 per cent. of the total energy in the circuit. In the case of 1250 metre transmission on the same aerial the loading would have to be equal to 1100 metres, and therefore the crystal and telephones are across 1100/1250 × 100 = 88 per cent. of the total energy. From the above it can be seen that in the case of 350 metre transmission (British) the coupled circuit is an advantage, while the local transmissions would require a coupling in which the losses were less than 12 per cent. to attain the same standard as the single circuits. But it is practically impossible to reduce the percentage losses to this small value.

*Telephones.*—It is most essential that high resistance telephones be used. The reason is not because they have high resistance, but because they are wound with a very large number of turns, and therefore owing to the high external resistance of the circuit, the magneto-motive force is increased to a greater extent than it is decreased by the higher resistance of the telephones. For example, if a coil of 10 turns and resistance 1 ohm is placed in a circuit of total resistance 100 ohms, then 1 volt will cause a current of 0.01 amps. The magneto-motive force will therefore be 0.01 × 10 turns =0.1. On the other hand, if the coil is wound with wire of one-tenth the area of cross-section the resistance will be 10 times greater; also there will be 10 times as many turns. In this case the resistance of the coil would be 10 × 10 × 1 = 100 ohms, which added to the resistance of the circuit (99 ohms) gives a total resistance of 199. Then 1 volt will cause a current of 0.005 amps. The magneto-motive force will therefore be .005 × 100 = 0.5. In the example given the increase in force is about 5 times. Now, if we examine the circuit diagram of a receiver we shall see that the telephones come in series with the crystal, which has a resistance of about 10,000 ohms, so the telephone resistance can be increased considerably without affecting the circuit.

The nature of the crystal used as a detector, and the amount of pressure placed on the contact, are vitally important in a set.

Ordinary galena gives very good results, but sensitive spots are hard to find. Most of the synthetic crystals now manufactured, such as Q.S.A., are very good. The condenser across the telephones is not necessary, there usually being sufficient self-capacity in the telephone windings, but it may be an improvement. Sets tuned by variometer or tapped inductance (for both of which circuits, I append full constructional details) undoubtedly yield the best results.

*Constructional Details.*—For the variometer sets the following components will be required:—Ebonite 7″ x 9½″, crystal detector and crystal, knob and dial, switch arm, 4 brass screw 1″ x ⅛″ whitworth and nuts, 3 brass screws ¾″ x 6 cask head variometer rotor and shaft assembly, 4oz. 24 G. enamel wire, 1 pair 4000 ohm telephones, 7″ cardboard tube 3¼″ inside diameter. The total cost will be about £3, with 10/- extra for an aerial equipment (without mast).

For the tapped coil the following is the list of components:—Ebonite 7″ x 9½″, crystal detector, 2 switch arms, 22 contact studs, 4 limit stops, 4 terminals and nuts, 4 brass screws 1″ x 7 cask head, 7″ cardboard, 3½″ diameter, headphones, 4oz., enamelled wire 24 G. The total cost for this circuit is about £3, with an additional 10/- for aerial equipment without masts.

*Working Details. Variometer.*—First wind the two halves of the rotor with the enamelled wire starting from the outside and working to the centre. Then clean and twist the centre pair together and solder. To the outside pair solder flexible pigtails. Care must be taken that the direction of the windings of the two halves is the same. Next commence winding the tube about ¼ inch from one end, place on 30 turns, then make a space of ½ inch and continue winding, taking off taps at turns Nos. 60, 100, 145, 200. See Fig. 1.

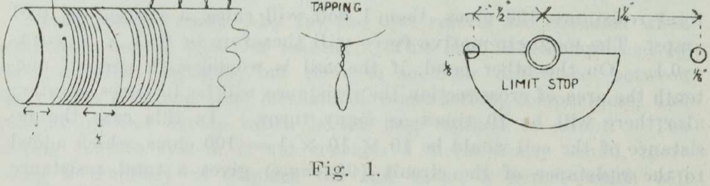


Fig. 1.

Two ¼ inch holes must now be drilled in the tube in the space between the windings, great care being taken to see they are diametrically opposite and at right angles to the axis of the tube.

Then drill ⅛″ hole ½″ from the centre of one of the ¼″ holes and another 1¼ inches away, but in the opposite direction, and through these place a ⅛″ whitworth screw from inside the tube and fasten with a nut. Proceed to assemble by pressing the brass bushes into the ¼″ holes from the inside, place the rotor in position and fix by passing the spindles through the bushes and screw-ing into the rotor. The hollow spindle must be placed in the bush nearest to the two screws. After securing with lock nuts, the limit stop is placed on the hollow spindle and the pigtails threaded through, one being secured to the end turn on the tube and the other to the remaining screw which is eventually connected to the aerial terminal.

The panel is next drilled and engraved, after which the various components are mounted and wired up as shown in Fig 2. The coil and variometer can be secured to the panel by two screws at the points marked C and B.

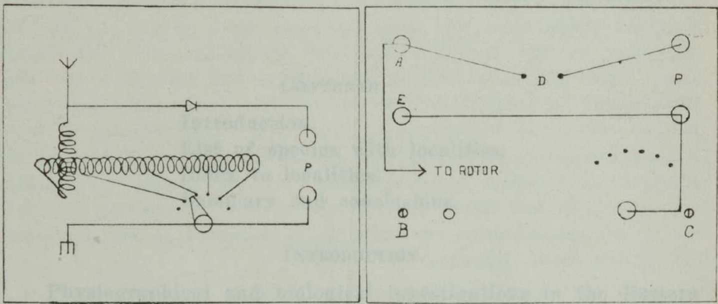


Fig. 2.—Variometer Set A, aerial; P, telephones; E, earth; D, detector. B, C, fixing screws.

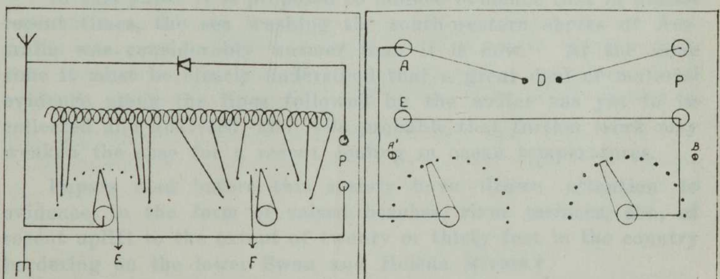


Fig. 3.—Tapped Coil Set. A, aerial; P, telephones; E (in right hand figure), earth; D, detector, A,' B, fixing screws; E (in left hand figure), 11-2 turn taps; F, 11·22 turn taps.

*The Tapped Coil.*—Wind a 7″ tube with 264 turns of 24 G enamel wire, making tapping points every 2 turns for the first 11 taps, and then every 22 turns for the next 11 taps. Connect the 11 2-turn taps to the studs of one switch arm, and the 11 22-turn taps to the studs of the other switch arm, and wire up as shown in Fig. 3.

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ing into the rotor. The bottom spindle must be placed in the hole nearest to the base screws. After securing with lock nuts, a light stop is placed on the bottom spindle, and the pigtails threaded through, one being soldered to the end turn on the tube and the other to base-holding screw which is previously connected to the aerial terminal.

The panel is next drilled and engraved, after which the various components are mounted and wired up as shown in Fig. 2. The coil and variometer can be secured to the panel by right-angle at the points marked b and b.

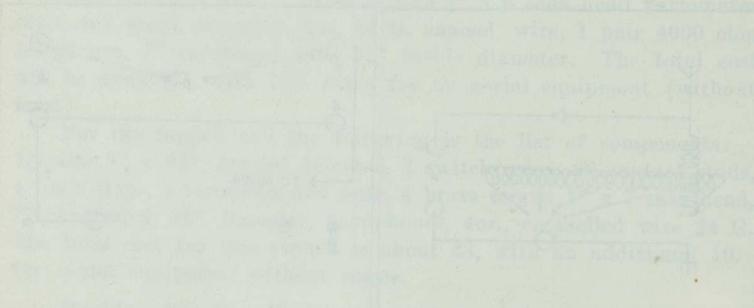

Fig. 2.—Variometer Set. A, aerial; T, telephones; E, earth; D, detector; C, fixing screws.

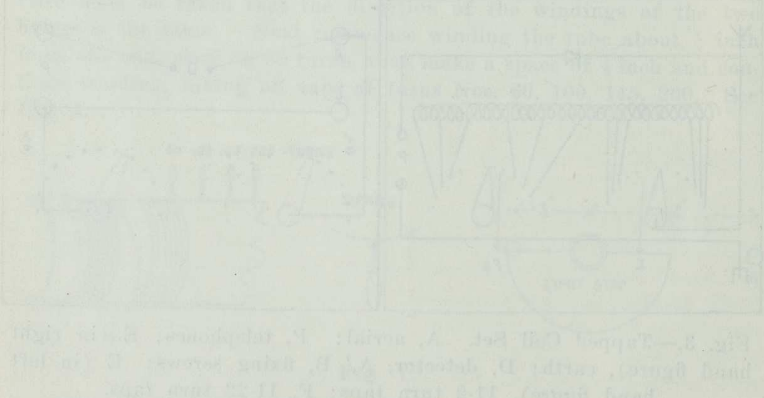

Fig. 3.—Tapped Coil Set. A, aerial; T, telephones; E, (in right hand figure), earth; D, detector; 4 B.A. fixing screws; E (in left hand figure), 11-2 turn tape; F, 11-22 turn tape.

The Tapped Coil. Wind a 3" tube with 264 turns of 24 S.W.G. enamel wire, making tapping points every 2 turns for the first 11 taps, and then every 22 turns for the next 11 taps. Connect the first eleven taps to the studs of one switch arm, and the 11 22-turn taps to the studs of the other switch arm, and wire up as shown in Fig. 3.